UNCLASSIFIED

AD NUMBER
AD352431
CLASSIFICATION CHANGES
TO: **unclassified**
FROM: **restricted**
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Foreign Government Information; JUL 1964. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.**
AUTHORITY
DSTL, DEFE 15/1980, 10 Dec 2008; DSTL, DEFE 15/1980, 10 Dec 2008

THIS PAGE IS UNCLASSIFIED

AD NUMBER
AD352431
CLASSIFICATION CHANGES
TO: restricted
FROM: confidential
AUTHORITY
RARDE Notice dtd 31 Mar 1969

33/64

~~CONFIDENTIAL~~

U. K. Restricted

COPY No. 66

Forwarded by:
US ARMY STANDARDIZATION GROUP
UNITED KINGDOM
USN 100 FPO, New York, N.Y.

AD 352 431

Decl OADR

EXCLUDED FROM AUTOMATIC REGRADING;
DOD DIR 5200.10 DOES NOT APPLY
GP 1

ROYAL ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

REGRADED U.K. Restricted BY AUTHORITY OF RARDE notice, 31 Mar 69 DD 70-1
DATED 1/22/70 BY

20080730 163

EXPLOSIVES DIVISION

R.A.R.D.E. MEMORANDUM 33/64

Blast damage - The use of scaled models in the experimental study of the effects of air blast on missile structures.

1. THIS INFORMATION IS DISCLOSED ONLY FOR OFFICIAL USE BY THE RECIPIENT GOVERNMENT AND SUCH OF ITS CONTRACTORS, UNDER SEAL OF SECRECY, AS MAY BE ENGAGED ON A DEFENCE PROJECT. DISCLOSURE TO ANY OTHER GOVERNMENT OR RELEASE TO THE PRESS OR IN ANY OTHER WAY WOULD BE A BREACH OF THESE CONDITIONS.

2. THE INFORMATION SHOULD BE SAFEGUARDED UNDER RULES DESIGNED TO GIVE THE SAME STANDARD OF SECURITY AS THAT MAINTAINED BY HER MAJESTY'S GOVERNMENT IN THE UNITED KINGDOM.

3. THE RECIPIENT IS WARNED THAT INFORMATION CONTAINED IN THIS DOCUMENT MAY BE SUBJECT TO PRIVATELY-OWNED RIGHTS.

F. King, et al
D. C. Clenshaw
R. F. Lankshear

EXCLUDED FROM AUTOMATIC
REGRADING: DOD DIR 5200.10
DOES NOT APPLY

Fort Halstead
Kent.

July,
1964

~~CONFIDENTIAL~~

U. K. Restricted

Reg #13331

(99) 107267 R

This Document was Graded
CONFIDENTIAL
at the 176th meeting of the R.A.R.D.E.
Security Classification Committee

R.A.R.D.E.
Printing Section

ROYAL ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

R.A.R.D.E. MEMORANDUM 33/64

Blast damage - The use of scaled models in the experimental study of the effects of air blast on missile structures.

F. King

D.C. Clenshaw

R.F. Lankshear

/c (E.CC)

Summary

The use of scaled models and conventional H.E. charges in the study of the effect of blast from nuclear explosions is discussed.

Experimental work using full scale and one-quarter scale models of a representative missile and conventional explosive charges of 64 lbs. and 4096 lbs. is described.

Approved for issue:

S.W. Coppock, Principal Superintendent, 'E' Division

CONTENTS

IMPORTANT

This document should be returned to the Reports Officer, Royal Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent. when no longer required

INITIAL DISTRIBUTION

Internal

No.	1	Director
	2	Deputy Director
	3	SMO
	4	PS/A
	5	PS/B
	6	PS/C
	7	PS/D
	8	PS/E
	9	Dr. W.M. Evans
	10	S/C3
	11	C3 (Att. Dr. P.J. Deas)
	12-14	F1 (Att. Mr. A.W. Bicker, Mr. D.C. Clenshaw, Mr. K. Jarvis)
	15	A3 (Att. Mr. F. King)
	16-18	C3 Registry

External (UK)

19	Chief Scientist, M of A
20	Chief Scientist (Army)
21	Deputy Chief Scientist (Army)
22	DG of Arty/Admin
23	D of Arty (R & D)
24	GW(G&C)5, M of A, Castlewood House
25	Army Department Branch Library, St.Christopher House
26	Secretary, OB
27	TIL1 (a), M of A, First Avenue House (Att.Miss M.J.Foreman)
28-29	TIL - for retention

[redacted]

U. K. Restricted

Overseas (through TIL)

No.	30	DRS (Att.Director of Munitions)
	31	British Defence Liaison Staff(Army) Ottawa (Att.Lt.Col.G.Burch,RA)
	32-36	Canada - Dept Nat Def
	37	- Nat Res Council
	38-41	- Def Res Board
	42	- CALE
	43-48	Australia - AAS(UK)
	49	- Dept of Supply
		- RAAF Overseas HQ, London
	50-67	USA - Joint Reading Panel
	68	- Assist Sec of Def (Dep DDR & E)
	69-70	- ONR(London)

Stock

71-80

1. INTRODUCTION

Early in 1958 there was considerable interest in the vulnerability of missiles to attack by nuclear weapons, particularly whilst on the ground in the period before launching. In an attempt to obtain information on this subject, a series of trials was planned using model and full scale targets exposed to a range of conventional charges. The full scale targets to be exposed were mock-ups similar in dimensions and construction to an early design of the English Electric Company's Blue Water, and were considered representative of general missile construction of this type. The model targets were made to the same drawings and were scaled geometrically by reducing all dimensions by a factor of 4.

2. APPROACH TO THE PROBLEM

During the First World War, Hopkinson (Reference 1) had suggested that the effects of blast on a target could be studied using scaled explosive charges and model targets made to the same drawings and of the same materials as the full scale targets, with only the linear dimensions being changed. There are certain restrictions on the use of this method of modelling. For instance, if the effects of gravity or viscosity of air play a significant part in the behaviour of the system it can be shown that a true model experiment cannot be performed. On a more practical level there may be great difficulties associated with the manufacture of a suitable model, particularly if the scale factor is large. However work that was already being carried out in X1 Branch and elsewhere (References 2,3,4) lent support to the idea that simple geometric models would be suitable in this instance. It should be emphasised that in cases where a 'true' model cannot be made, some form of model experiment may be the only practical approach to a problem.

Hopkinson's method of modelling states that if a target suffers a certain degree of damage at a pressure level 'p' p.s.i. when exposed to the blast from W lbs. of explosive, then a 1/nth. scale model will suffer the same degree of damage when exposed to the same pressure level 'p' p.s.i. to the blast from W/n^3 lbs. of explosive. Table I gives the relationship between various charge and target parameters for both full scale and model systems.

3. DESIGN OF EXPERIMENT

The object of the programme was to determine the distance from a nuclear explosion at which the air frame of Blue Water would be just damaged. At the same time strain and acceleration measurements were to be made, subject to the availability of suitable recording equipment. The term 'just damaged' refers to the condition where the target suffers the minimum permanent deformation, this being judged by eye or touch. It has been found in practice that this point is well defined in the case of most thin-walled structures where failure is caused by elastic instability (Reference 5) rather than by actual failure of the target material.

At the time this work was undertaken the only available version of Blue Water was an early 'mock-up' used for handling trials, the drawings of which were obtained from the English Electric Company. It was decided that full scale and one quarter scale models would be manufactured to these drawings.

These targets were to be exposed to the blast from 64lb. and 4096lb. charges of plastic explosive (P.E.2), the ratio of the charge weights being the cube of the scale factor, as is required for geometric modelling. A smaller charge (1lb.) could also be included in the series if it seemed desirable at a later stage.

The first stage of the experiment was to find the distance and pressure level for damage of the quarter scale models against a 64lb. charge. This distance multiplied by 4 would give the damage distance for the full scale targets (assuming modelling to be correct) against 4096lbs. This distance was to be confirmed by exposing the full scale missiles. At the same time a damage distance was to be determined for the quarter scale models against 4096lbs. This would determine the damage distance for the full scale against 4096 x 4^3lbs. (approximately 120 tons). This distance could be confirmed at Suffield and also a damage distance obtained for the quarter scale exposed to the same charge weight. This latter result would be equivalent to exposing the full scale missile to 120 x 4^3 tons approximately 7.5 kilotons of TNT, which is the blast output of an atomic weapon of about 16 kilotons total yield.

From the results of these firings a curve could be plotted of the critical damage distance R against the charge weight W (Figure I). If the method of scaling employed is correct all the experimental points would lie on the same curve, after being scaled by the appropriate factors. When plotted on log-log paper a rough straight line would result; this has been confirmed from a number of blast trials (Reference 2). Should the method of scaling be incorrect the result would be two parallel R vs W curves (Figure 2) which would still provide a certain amount of information. The R vs W curve can be converted into the more conventional Pressure-Duration damage curve if required (Figure 3). The R vs W curve is constructed as follows: if a quarter scale target is damaged at a distance R from a charge W, the point 4R and 4^3W is plotted. This point is confirmed by finding the damage distance for a full scale target exposed to 4^3W lbs., this distance should be 4R (if modelling is correct).

4. TARGET DETAILS

Blue Water is a tactical surface-to-surface weapon using a solid fuel motor. For ease of handling in the field it consists of 3 major assemblies, the solid fuel motor, the guidance and electronics bay and the warhead bay, which are bolted together a short time before firing.

Each of the two forward assemblies are made up of three sub units which are bolted together in a similar manner to the major assemblies.

Each unit consists of two forged and machined duralumin strong rings and a thin skin of duralumin which is riveted to the strong rings. Internal components are fixed to the skin or to the strong rings. In the version of Blue Water used for this work, mild steel ballast weights were bolted to a tube in each section, which was in turn attached to the strong rings by means of a mild steel spider, to bring the target weight up to the design value. Figure 4 shows the construction of the target used. Table 2 gives details of the targets, both full scale and model scale. The targets were to be supported in two ways:

(a) Mounted horizontally in a cradle, supported at two points (See Figure 5). This is the position in which the missile is carried on the launching vehicle until it is moved on to the launcher immediately before firing.

(b) Suspended at two points (Figure 6) from a zero length launcher beam. Both methods of support were designed for easy fixing to the ground in the desired position relative to the explosive charge. The full scale supports were anchored by approximately 5 tons of steel plate being placed on the base. Angle pickets and sandbags were used to secure the model supports.

5. INSTRUMENTATION

On all firings the blast wave was monitored using the H.3 blast gauge (Reference 6) feeding into a commercial four-channel oscilloscope to give the peak pressure, impulse and duration at the various targets being exposed.

Piezo-electric accelerometers and suitable cathode ray oscillograph recording gear were used to measure the acceleration-time history of selected parts of the guidance bay (Section D). Figure 7 shows the layout of these accelerometers on the quarter scale models. The positioning was similar on the full scale missile. Four instruments were used on each target, two measuring accelerations in a vertical plane, and two in a horizontal direction away from Ground Zero.

Wire strain gauges were attached to the inside of the missile skin in sections C, D and E as illustrated in Figure 8. The low frequency recording gear available at the time, (250 cps natural frequency galvanometer elements) meant that vibrations of the skin due to the impact of the shock wave would not be recorded, but only the lower frequency flexing of the complete missile.

Four high speed cine cameras (2000 pps) were used in an attempt to record the behaviour of the targets under the action of the blast waves. Several GSAP gun cameras (64 pps) were used to obtain general 'shots' of the target area.

6. EXPERIMENTAL LAYOUT

Sixteen spherical 64lb. charges of P.E.2 were fired and in order to reduce cratering and prevent debris being thrown, they were fired at a height of 2 feet above a steel plate placed on the ground (Figure 9).

12 quarter scale missiles (6 on launchers and 6 on cradles) were exposed to each round, oriented 'side-on' to the blast wave i.e. the centre line of the missile was perpendicular to the direction of propagation of the blast wave. On the first round the missiles were spaced around the charge at an expected pressure level of 1.5 p.s.i. On succeeding rounds the targets were gradually moved nearer to the charge, being carefully examined after each firing for any signs of damage. When damage was detected (see Para 7) the same target conditions were maintained for the next round as a check on the repeatability of the experiment.

Next, two 4096lb. charges were fired, both full scale and model targets being exposed on each round. This charge (Reference 7) was cylindrical in shape and was mounted at a height of 9ft.6ins. above a 15ft x 15ft x 6ins., steel plate (Figure 10) for reasons already mentioned.

Targets of both sizes were deployed at various pressure levels at which it was hoped that the damage sustained would range from severe to no damage in order to obtain the critical damage distance.

7. RESULTS

7.1 Structural damage

No permanent deformation of the quarter scale missile skin was detected until Round 10 when a number of missiles sustained slight damage to section C and D (See Table 3). Missiles had been blown off the launchers at lower pressures but this had caused no skin damage although the launching hooks had been broken. These hooks were redesigned and caused no further trouble.

A full scale missile exposed on a 64lb. firing to test instrumentation, sustained quite serious damage at a pressure level where a quarter scale missile was only slightly damaged. At the time this was thought to be due to some fault in the riveting of the skin to the strong ring (see Para.9) of this particular missile.

On the first of the 4096lb. charges the full scale missiles were damaged at a lower pressure than that suggested by the 64lb. firings against quarter scale targets. On this round no quarter scale missiles were damaged except those blown off the launchers.

The second large charge was fired to confirm the damage distance obtained on the previous round for the full scale targets, and to obtain a damage distance for the quarter scale models by exposing them at higher pressure levels.

The results of these firings are summarised in Table 3. It is apparent from this table that the modelling laws were not holding, but the reason for this soon became clear and is fully dealt with in the Discussion (Para. 8).

7.2 Acceleration measurements

Although the accelerometers and recording equipment were considered suitable for the task, the resulting records proved difficult to analyse.

This was due, in the main, to the unrealistic manner in which the internal ballast weights were made up and secured to the airframe. There was a large number of metal to metal contacts and no form of anti-vibration mounting.

Figure 11 shows the form of the acceleration-time records obtained. One model missile was exposed a sufficient number of times at different pressure levels to make it possible to plot the peak acceleration-distance curve, (Figure 12) and the peak acceleration-peak pressure curve (Figure 13).

7.3 Strain measurements

The type of records obtained using the galvanometer recorders (with 250 c/s elements) is shown in Figure 14. From these records it is possible to determine the frequency of flexural vibration of the whole missile as tabulated in Table 4. It can be seen that the ratio of the frequencies approximates to the scale factor (cf. Table 1) whilst the frequency is independent of charge weight as should be the case.

It is not possible to determine the high frequency strains set up in the missile skin. However one or two strain gauge records were made using CRO equipment and were of the form shown in Figure 15.

7.4 Blast measurements

The 'side-on' pressure, impulse and duration associated with the blast waves were monitored on each round. This work is reported separately (Reference 6) but the relevant data is summarised in Figures 16, 17 and 18.

8. DISCUSSION OF RESULTS

8.1 Structural damage

The main point arising from the firings was the fact that apparently the method of scaling adopted was invalid. The full scale missiles were being damaged at lower pressure levels than the quarter scale models. The skin damage was accompanied by large scale rivet failure, and again it was suspected that there was some error in the riveting.

Damaged and undamaged missile section were carefully examined by Engineering Section, R.A.R.D.E., particular attention being paid to the rivets. No fault could be found with the rivets, but it was noted that the skin material of section C of all quarter scale missiles examined was 0.003 inches too thick. This was, however, within the normal commercial tolerance for the gauge of metal concerned.

On the full scale missiles section C was skinned with 15 SWG ($0.072'' \pm 0.005''$) aluminium alloy (L72), and the skin of the same section of the models should be one quarter the thickness, that is 26 SWG (.018"). The tolerance of this gauge is $\pm$ 0.003". The material used on the full scale section C was very close to the nominal .072", but the quarter scale material was all + 0.003", that is 17% too thick. The critical pressure at which elastic buckling occurs for such thin walled structures (Reference 5) is roughly proportional to the cube of the wall thickness (t^3), and therefore the quarter scale missiles were about 50% stronger (pressure-wise) than they should have been. The pressure levels for targets to be just damaged, using scaled charges, was 15 p.s.i. for the full scale and 22 p.s.i. for the quarter scale models, the figure for the quarter scale being approximately 50% higher than for the full scale.

Sections of missiles were tested to find the static failure pressure by being immersed in water in a steel tank. The pressure was applied by pressurising a small air space at the top of the tank. The target sections were sealed to prevent the ingress of water whilst the inside of the target was open to atmospheric pressure. Unfortunately the opening of the steel tank was too small to admit section C of a full scale missile and therefore a direct comparison between the sections most susceptible to damage was impossible. Tests were carried out on section B of both full size and model missiles (see Table 5). The skin material in these sections is the same as in section C.

In every case the full scale section failed at a lower pressure than the corresponding model section. The results of these static pressure tests are given in Table 5.

As a result of the pressure tests and mechanical examination of the missiles, it was decided that section C of the quarter scale missile should be re-skinned with selected material of the correct thickness ($0.018'' \pm 0.001''$). It was also felt that the target was not sufficiently realistic, in that the manner in which the ballast weights were mounted added a considerable amount of stiffness to the structure. In the actual Blue Water missile all loads are carried by the skin. To reduce this stiffness it was decided that the ballast weights in section C and D should be carried on suitable anti-vibration mounts. This would also reduce some of the difficulties encountered in the acceleration measurements.

8.2 Acceleration measurements

It was expected that the acceleration records would be difficult to analyse, although it was hoped to obtain 'better' and more reproducible records than were actually obtained. It is felt that these records are of limited value as the ballast weights on which the accelerometers were mounted are totally unrealistic. These consist of a number of flat steel plates threaded on a steel pipe, clamped between two 'spiders' which are in turn bolted to the strong rings. There was a great deal of metal to metal contact and no form of anti-vibration mounting, consequently the 'ringing' of the various components contributed to the accelerometer output. Owing to the nature of the records it has not been possible to check the acceleration scale mentioned in Para.2.

8.3 Strain measurements

As has already been briefly mentioned, the strain gauge measuring system, employing 250 c/s galvanometers could only measure low frequency strains. The 'panel' strains set up in the skin as a result of the incipient blast loading were therefore missed and only the low frequency 'lever' strains resulting from the slow flexure of the missile as a whole, were recorded. It was decided therefore to obtain higher frequency recorders.

9. REVISED PROGRAMME

After firing the second 4096lb. charge the following changes were made to the programme.

(a) Section C of the quarter scale missiles was reskinned with material of correct thickness (0.018" ± 0.001"). Sections C and D were the only sections to suffer blast damage under the conditions of the trial, and the skin of section D was of the correct thickness.

(b) The ballast weights in sections C and D of both the full scale and quarter scale missiles were supported on anti-vibration mountings. The reasons for this change are given in Paragraph 8.1. The mountings were designed so that the load-deflection curves for the two targets were suitably scaled. Figure 19 shows the modified mounting.

(c) All missiles were exposed on cradles. The missile is on the launcher for only a very short time before firing, and the chances of being attacked in that condition are small. A modified cradle was used, supporting the target at the rear of the rocket motor and at the strong-rings between section C and D (Figure 20). Previously the forward support was at the middle of section E.

(d) The strain measurements were confined to section C. The 12 strain recording channels available for one missile were concentrated in this section to get a more detailed picture of the strain-time history over the portion of the target most susceptible to damage.

(e) Higher frequency (3000 cps) galvanometer elements were obtained, together with suitable driver amplifiers for the strain recording system.

10. SUFFIELD TRIAL 1960

Six modified (see 9a and 9b) quarter scale missiles were exposed to a 40,000lb TNT firing at Suffield in August 1960, at pressure levels ranging from 24 p.s.i. down to 5 p.s.i. The main objective was to determine the pressure level for this particular charge weight, at which the missile skin was just damaged.

As can be seen from Table 6, the primary object of the trial was achieved, the critical pressure being 11.3 p.s.i.

Two missiles (numbers 20 and 24) were instrumented with accelerometers and strain gauges. The strain gauges were cemented to the skin of Section C to record both circumferential and longitudinal strain. Accelerometers were mounted on a shock isolating block in the same nose cone section. They were positioned transversely to the missile axis to record both vertical and horizontal accelerations. The results obtained are shown in Table 7.

11 FUTURE WORK

On a visit to the U.K. Mr. J. Sperrazza of Ballistic Research Laboratories (B.R.L.), expressed a keen interest in this study. After some discussion, it was agreed that B.R.L. would complete the experimental work. The full scale and quarter scale missiles were therefore shipped to U.S., in order that the remainder of the work could be carried out, both at B.R.L. and Suffield.

12 CONCLUSIONS

The Blue Water trials formed part of a blast damage programme being carried out by X.1 Branch, R.A.R.D.E. Work was stopped on this programme at the end of 1960 after the Canadian trial.

In order to complete the programme as set out in Paragraph 3 it is necessary to expose full scale missiles, modified according to Paragraph 9, to a large explosion of the order of 100 tons (128 tons would be ideal, being the next step up from 4096 lbs.). It is also necessary to expose the modified quarter scale targets to a 64 lb. charge to get a damage point at the other end of the scale.

Owing to the incomplete nature of the experiments it has not been possible to establish with certainty that the simple form of modelling used is correct, although all the indications from this series of tests and from previous work (Reference 2) point in that direction. A good deal of information on the effects of blast on light structures has been obtained.

13 REFERENCES

1. Structural Damage 1945 (Chapter 6) D.G. Christopherson R.C. 450

2. A.R.D.E. Memo. (MX) 86/60
An experimental study of the effects of air blast on simple conical targets. D.C. Clenshaw

3. B.R.L. Report 1011
Blast effects tests of a one-quarter scale model of outer containment structures for nuclear reactors. W.E. Baker and J.D. Patterson

4. B.R.L. Report 1067
Laws for large elastic response and permanent deformation of model structures subject to blast loading. W.E. Baker et al.

5. Theory of Elastic Stability (Chapters 8 and 9) S. Timoshenko
McGraw-Hill 1936

6. A.R.D.E. Memo MX 54/60
The measurement of air blast: the H3 blast gauge. K.J. Jarvis et al.

TABLE I

Charge	Full Scale	Model
Weight of charge (lbs)	W	W/n^3
Pressure (psi)	p	p
Radius from charge for same 'p' (ft)	R	R/n
Duration (mSecs)	τ	τ/n
Impulse (lbs/in^2 mSecs)	I	I/n
Target		
Length	l	l/n
Mass	M	M/n^3
Area	A	A/n^2
Displacement	δ	δ/n
Velocity	v	v
Acceleration	a	na
Strain	ϵ	ϵ
Rate of Strain	S	nS
Natural frequency	f	nf

TABLE 2

Item	Full Scale			
	Weight lbs.	Length ins.	Diameter ins.	Skin thickness ins.
Nose Cone (Sect.A + B + C)	900	96	24	0.072 (15 SWG)
Forward Centre body (Sect.D)	475	28	24	0.104 (12 SWG)
Centre Section Centre body (Sect.E)	632	45	24	0.114 (11 SWG)
Aft Section Centre body (Sec. F.)	200	30	24	0.104 (12 SWG)
Motor Tube filled	3170	150 inc.tail pipe	24	$\frac{3}{8}$ (Mild Steel)
Complete missile	5377	349	24	-
$\frac{1}{4}$ scale				
Nose Cone (Sec.A + B + C)	14.06	24	6	0.018 (26 SWG)
Forward Centre body (Sec. D)	7.31	7	6	0.024 (23 SWG)
Centre Section Centre body (Sec.E)	9.97	11.25	6	0.028 (22 SWG)
Aft.Sec.Centre body (Sec.F)	3.02	7.5	6	0.024 (23 SWG)
Motor Tube,filled	52.56	37.5	6	3/32 (mild steel)
Complete missile	86.94	87.25	6	-

TABLE 3

Target	Charge Weight	Distance from charge	Pressure level	Result
$\frac{1}{4}$-scale Missile	64 lb.	30 ft.	23 psi	Just damaged
Full scale Missile	4096 lb.	140 ft.	16 spi	Just damaged
$\frac{1}{4}$-scale Missile	4096 lb.	130 ft.	19 psi	Undamaged

TABLE 4

Target	Charge Weight	Flexural Vibration Frequency	Round No.
Full Scale Missile	64 lb.	6.5 c/s	15
$\frac{1}{4}$-scale Missile	64 lb.	30.0 c/s	15
Full Scale Missile	4096 lb.	6.5 c/s	17
$\frac{1}{4}$-Scale Missile	4096 lb.	30.0 c/s	17

TABLE 5

Results of Static Pressure Trials				
Scale	Serial No.	Missile Section	Failure Pressure p.s.i.	Skin thickness
$\frac{1}{4}$	2	B	27.5	.021"
$\frac{1}{4}$	19	B	28.0	.021"
Full	11	B	22.0	.072"

TABLE 6

Missile No.	Pressure p.s.i.	Damage
27	24	Sections B & C: Heavy Damage
12	16.5	Section C: Moderate Damage
18	13.5	Section C: Light Damage
23	11.3	Section C: Just Damage
20	8.0	No Damage
24	5.6	No Damage

TABLE 7

Missile No.	Vertical Accn.	Horizontal Accn.	Vibration Frequency
20	58g	42g	30 - 40 c/s
24	57g	31g	30 - 40 c/s
Missile No.	Peak Circumferential Strain and Frequencies		Peak Longitudinal Strain and Frequencies
20	0.010% - 0.025% @ 600 c/s		0.010% - 0.025% @ 40 c/s
24	Not analysed due to high hum level.		

 FIGS. 1 AND 2

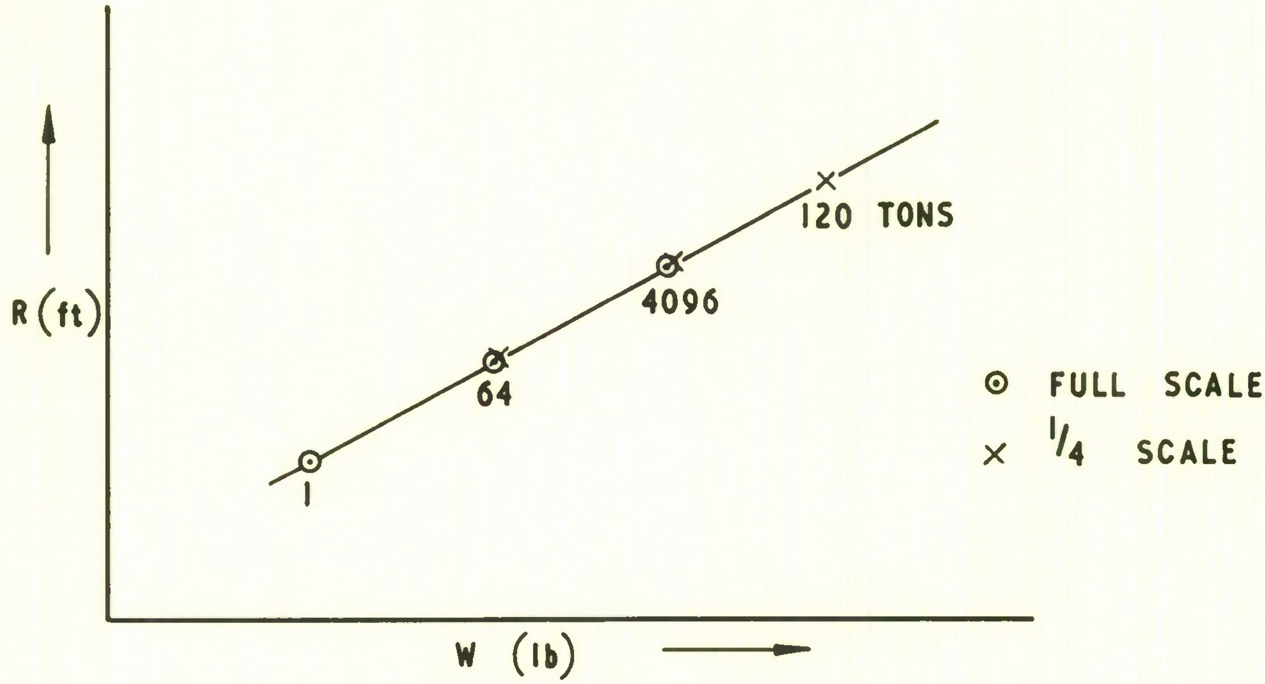

FIG. 1 RADIUS – CHARGE WEIGHT DAMAGE CURVE

ACCURATE MODELLING

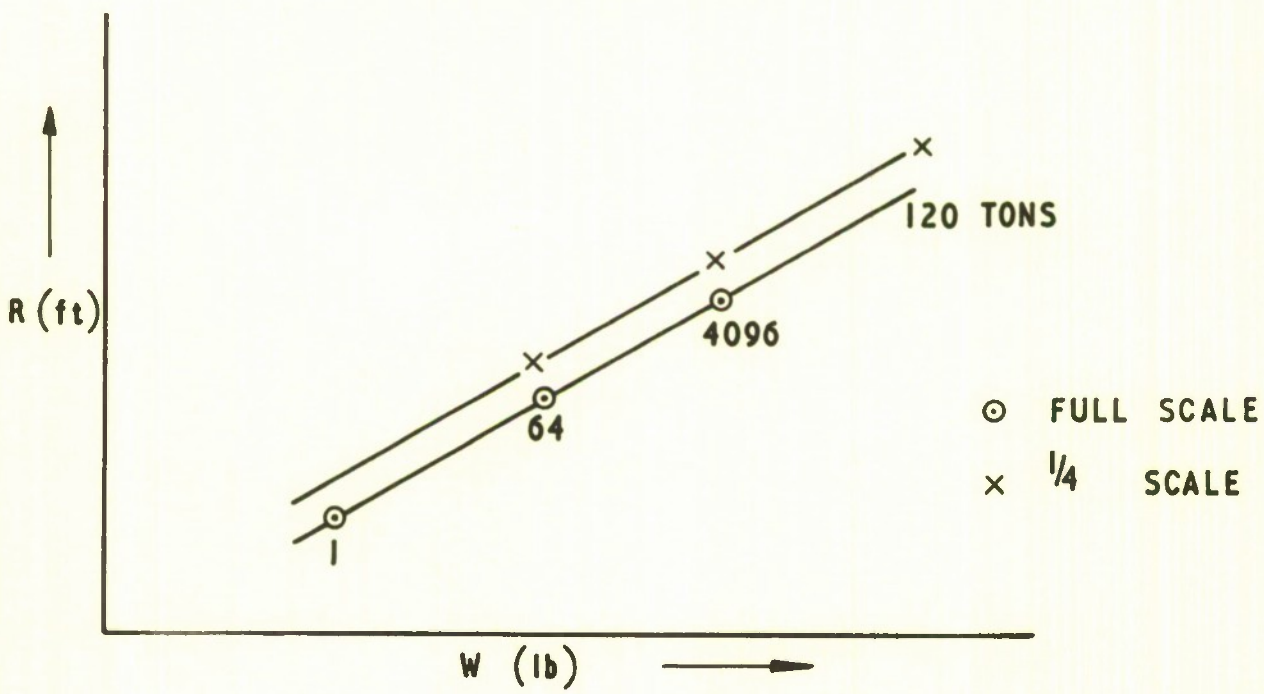

FIG. 2 RADIUS – CHARGE WEIGHT DAMAGE CURVE

INACCURATE MODELLING

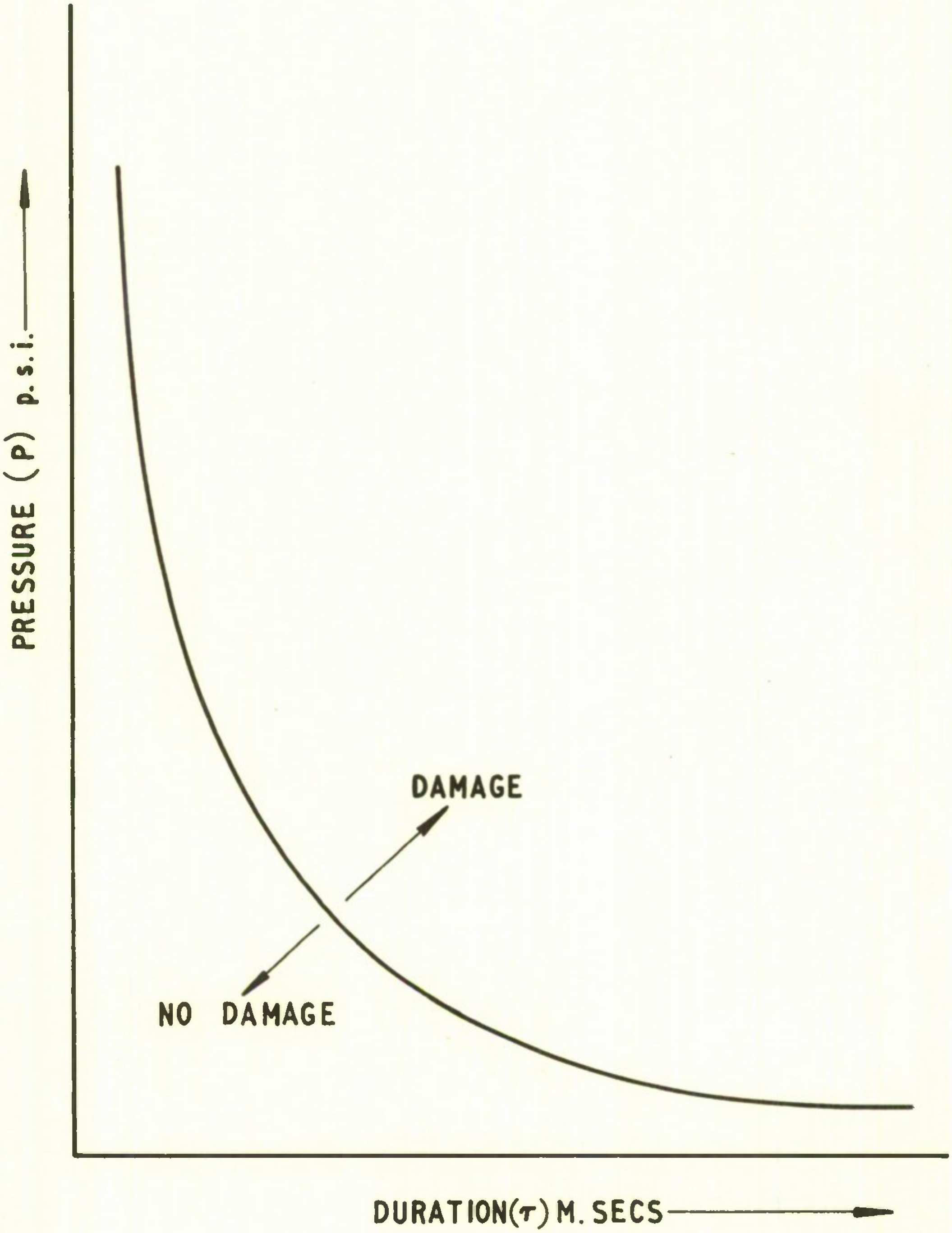

FIG. 3 PRESSURE - DURATION DAMAGE CURVE

CONFIDENTIAL

FIG. 4

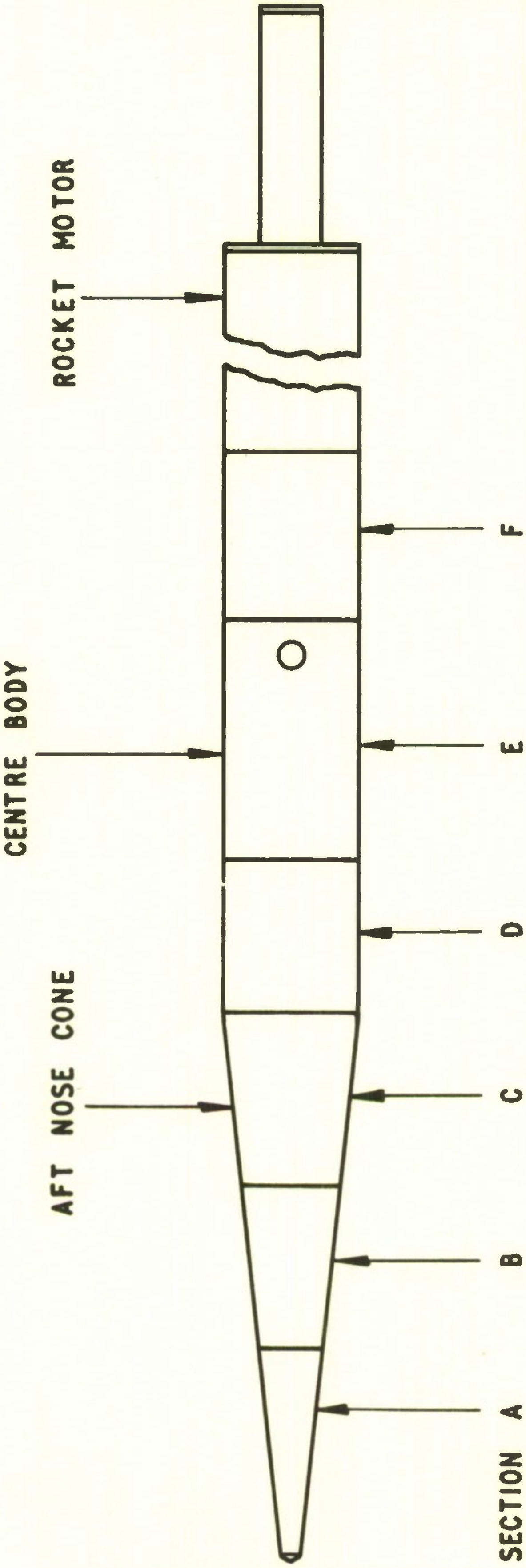

FIG. 4 SKETCH OF MISSILE TARGET

CONFIDENTIAL

FIG. 5

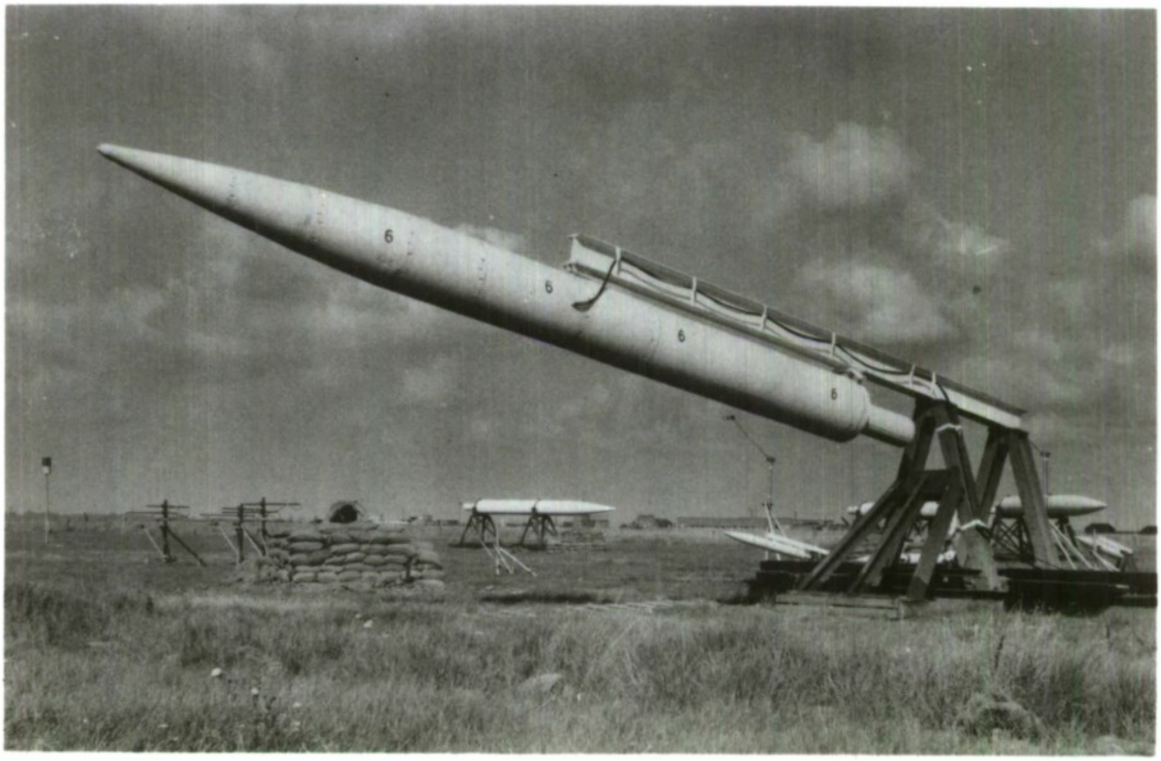

FIG. 6

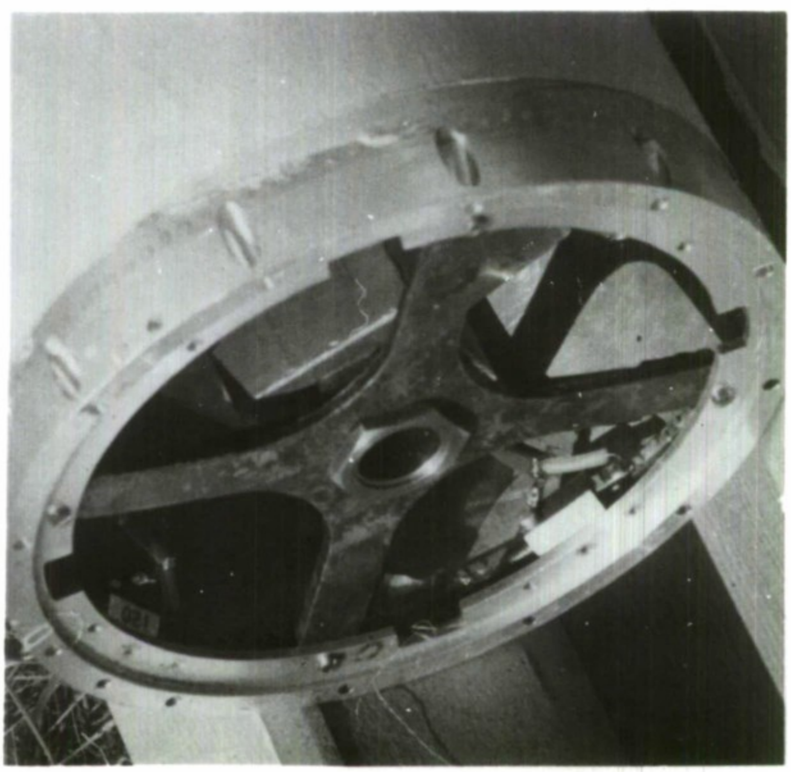

FIG. 7 LAYOUT OF ACCELEROMETER ON $^1/_4$ SCALE MISSILE

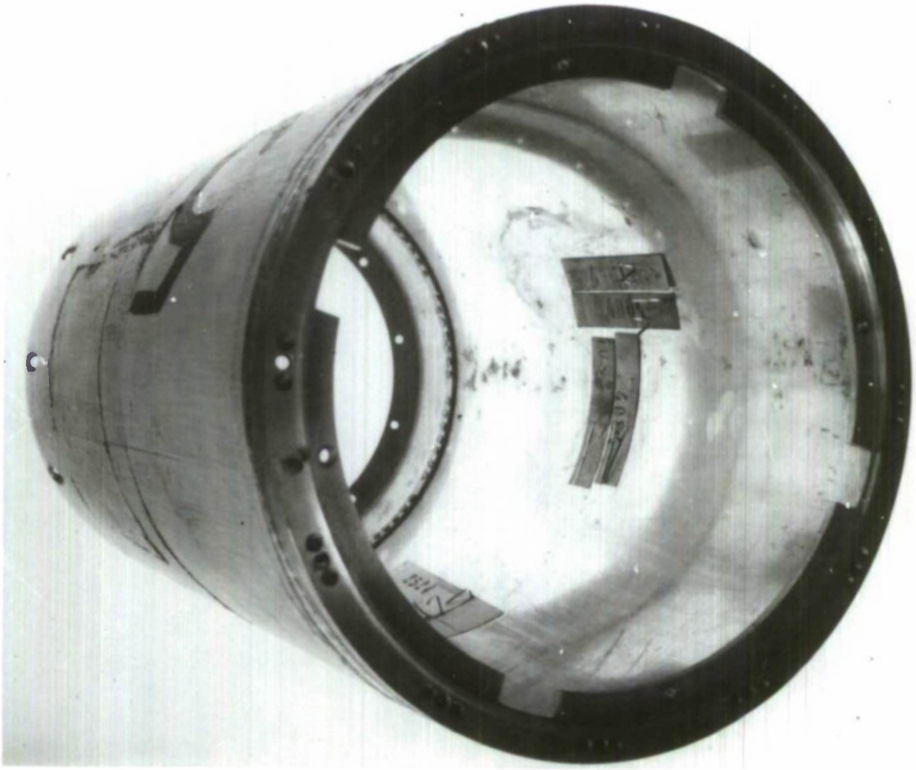

FIG. 8 LAYOUT OF STRAIN GAUGES IN SECTION OF $^1/_4$ SCALE MISSILE

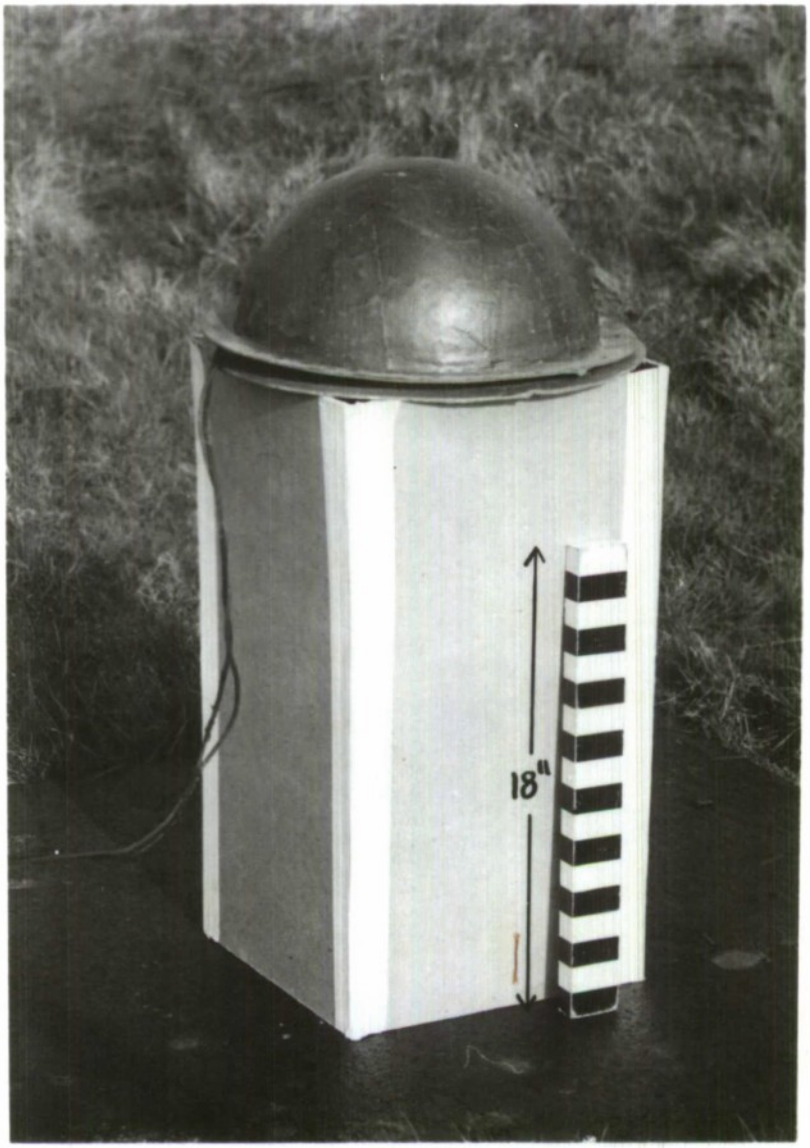

FIG. 9 64 LB CHARGE IN POSITION

FIG. 10 4096 LB CHARGE IN POSITION

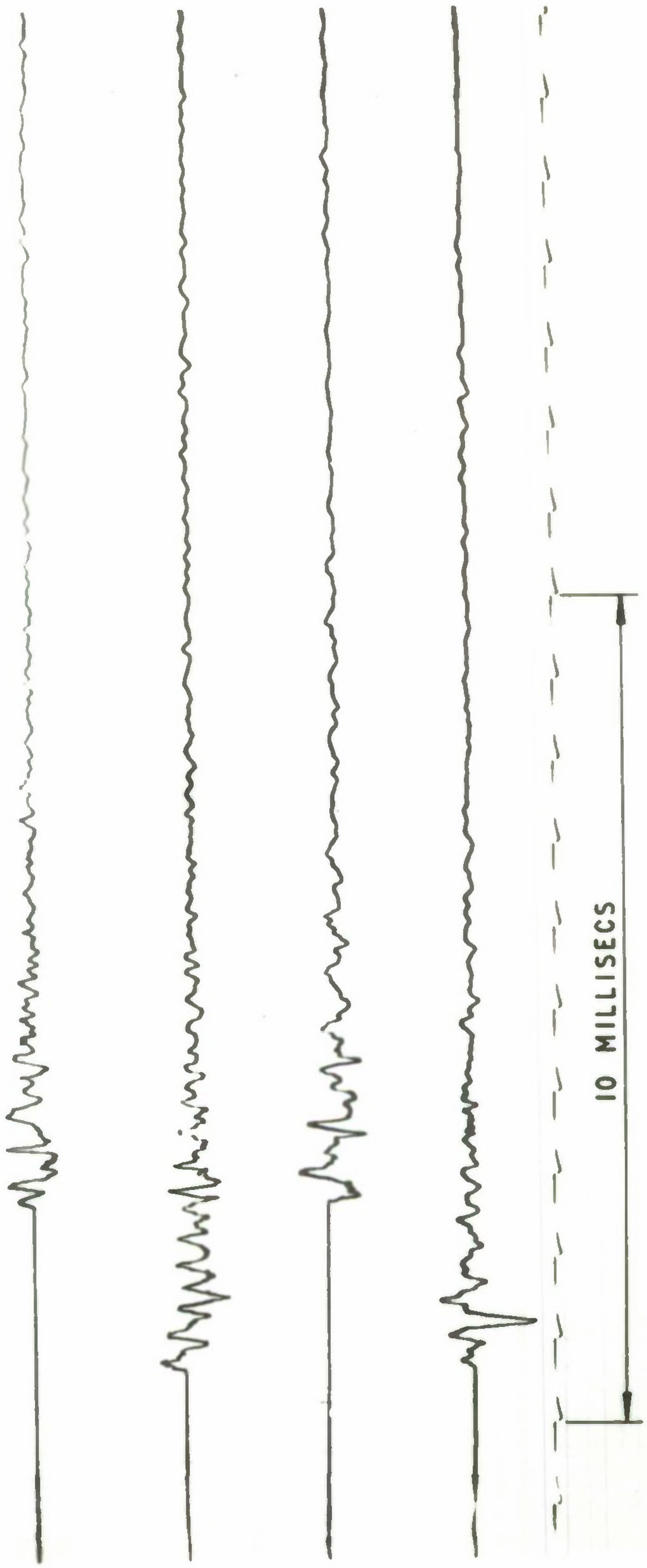

FIG. 11 TYPICAL ACCELERATION - TIME RECORD

CONFIDENTIAL

FIG.12

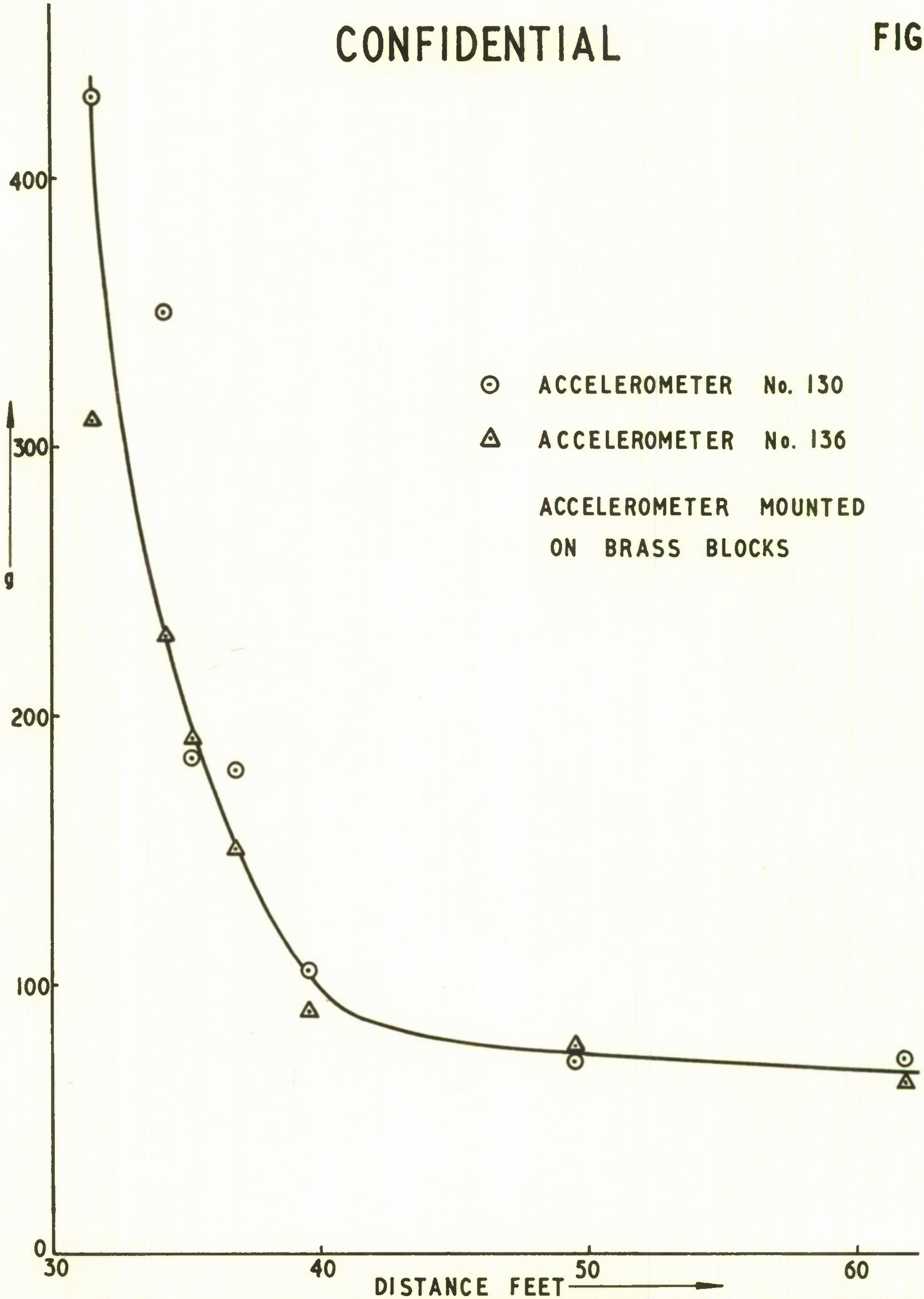

FIG. 12 PLOT OF PEAK ACCELERATION-DISTANCE FOR 64 LB. CHARGE

CONFIDENTIAL

CONFIDENTIAL

FIG. 13

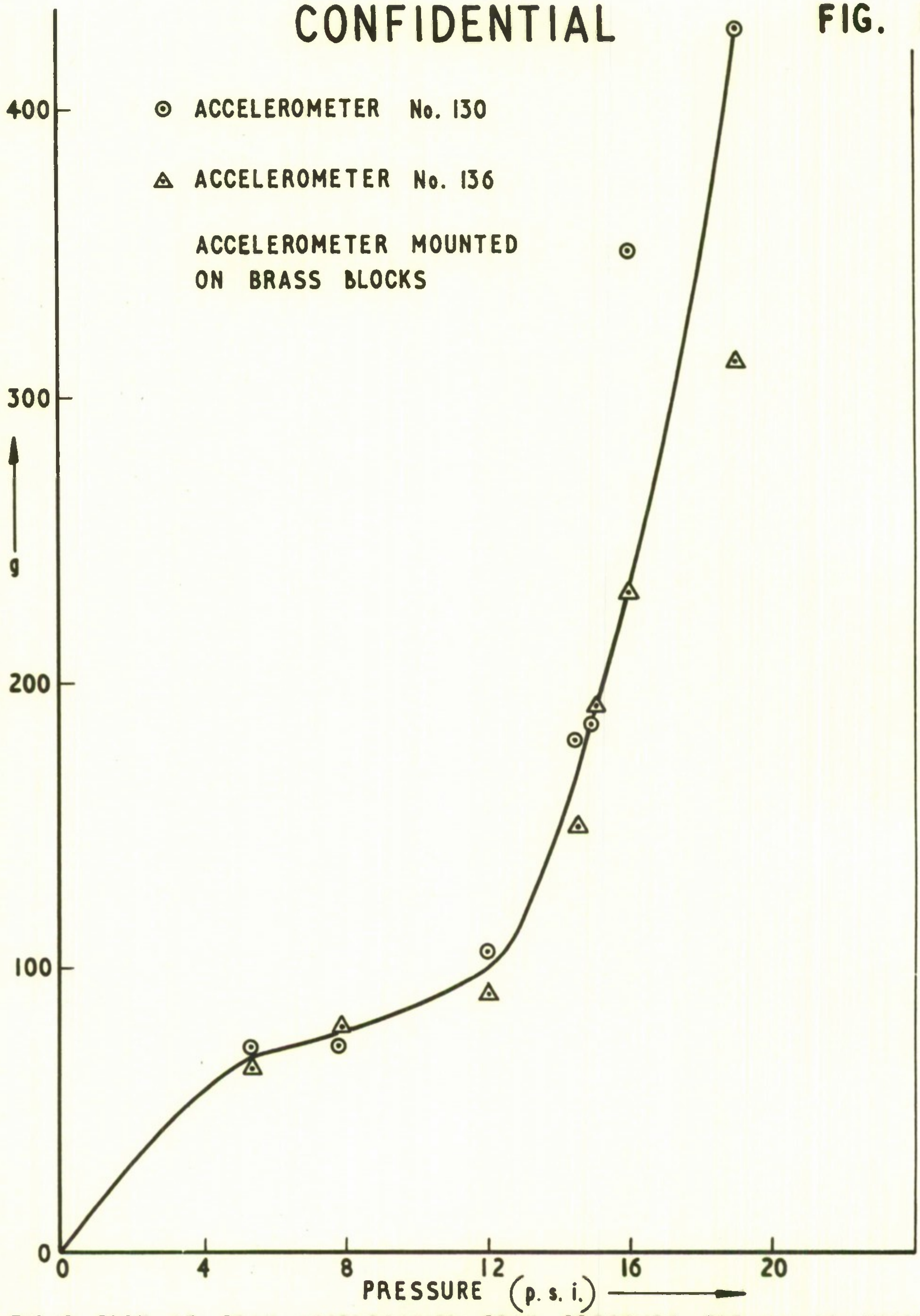

FIG.13 PLOT OF PEAK ACCELERATION-PEAK PRESSURE FOR 64 LB CHARGE

CONFIDENTIAL

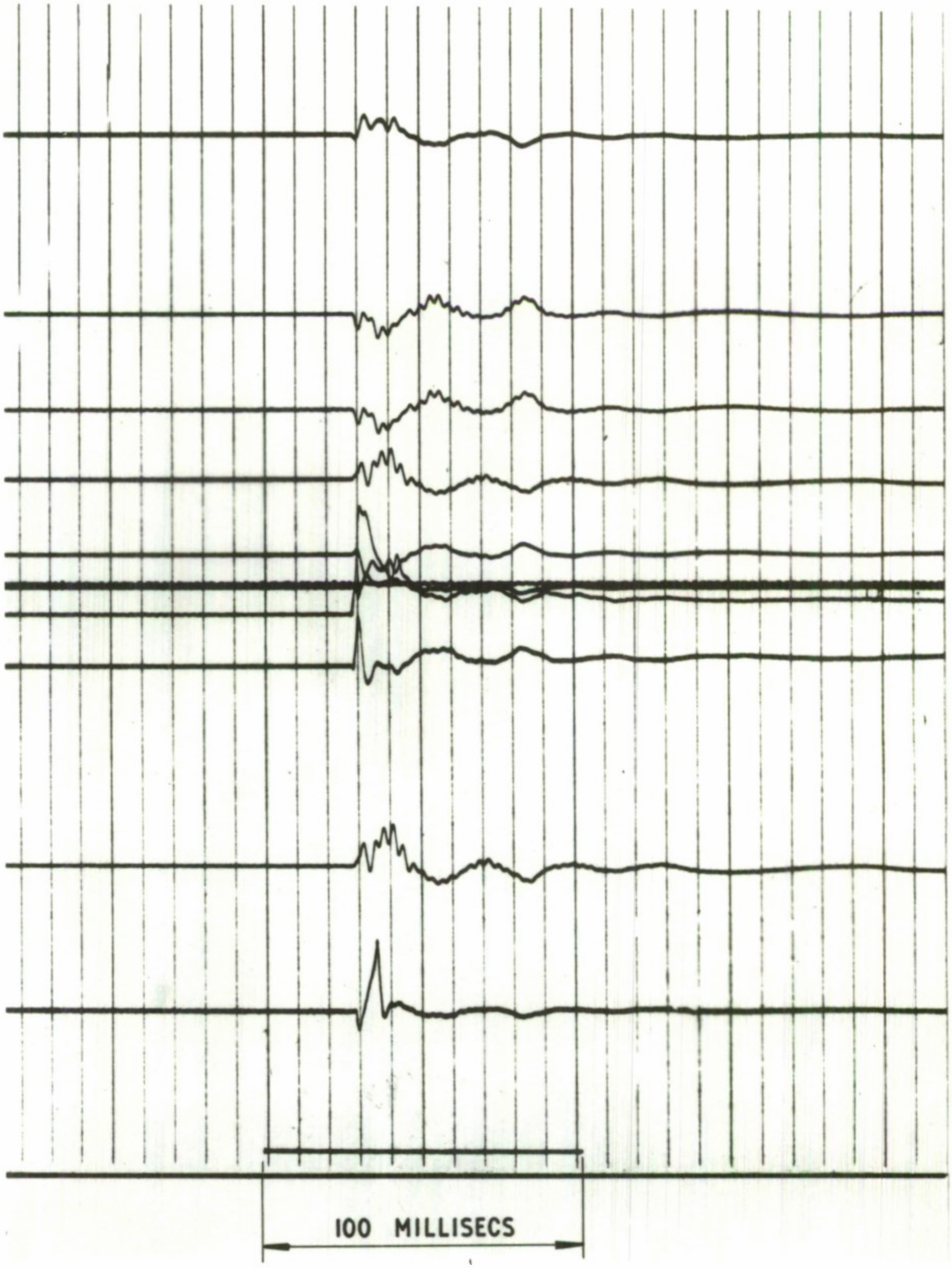

FIG. 14 STRAIN - TIME RECORD OBTAINED WITH 250 c/s GALVO

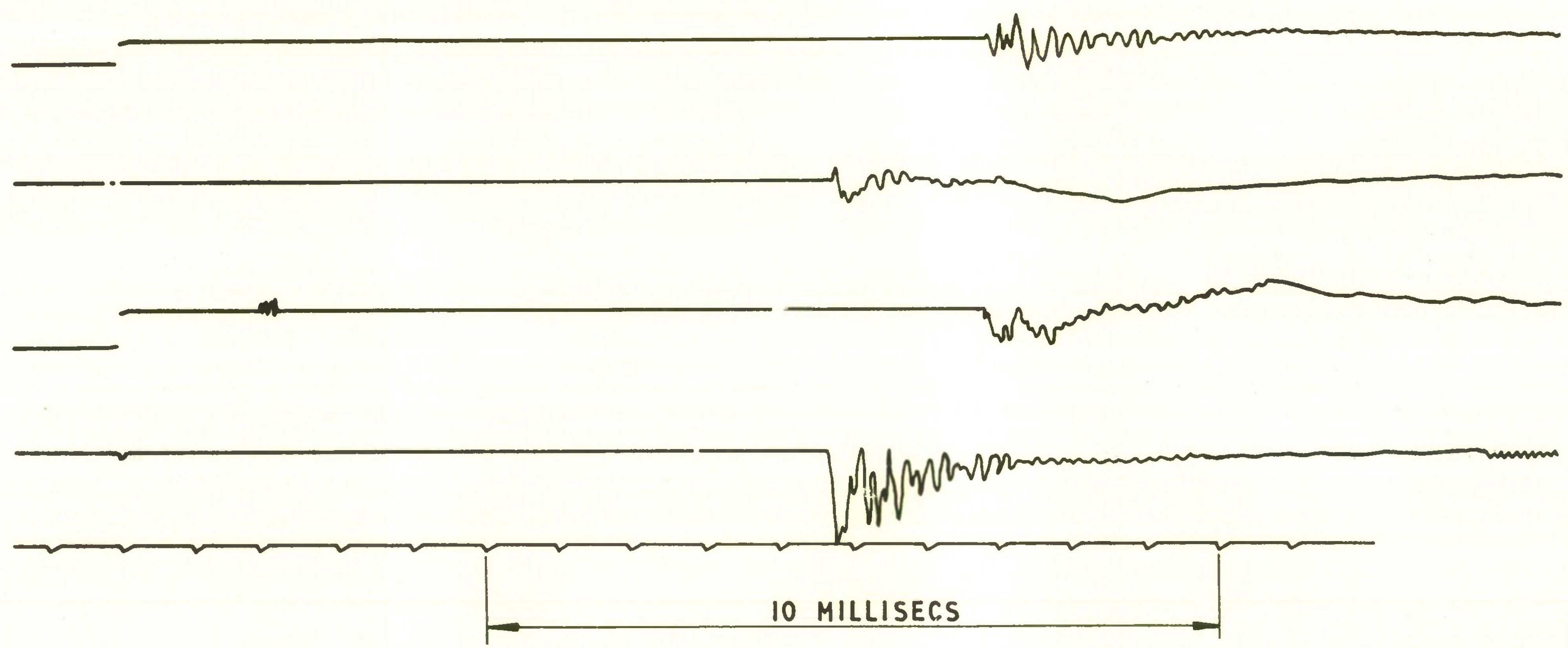

FIG. 15 STRAIN - TIME RECORD OBTAINED WITH CRO RECORDER

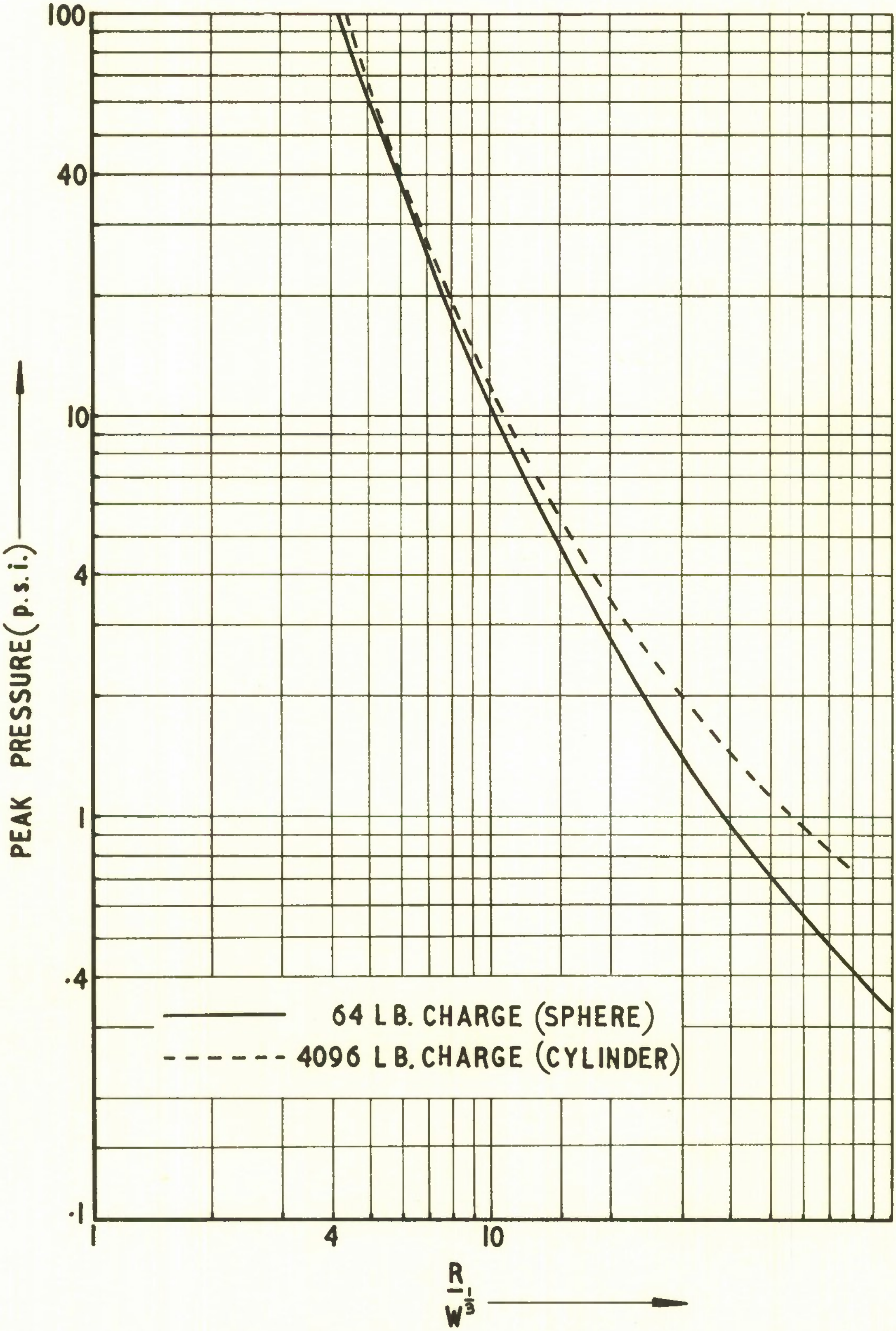

FIG. 16 PEAK PRESSURE-DISTANCE CURVES FOR 64 AND 4096 LB CHARGES

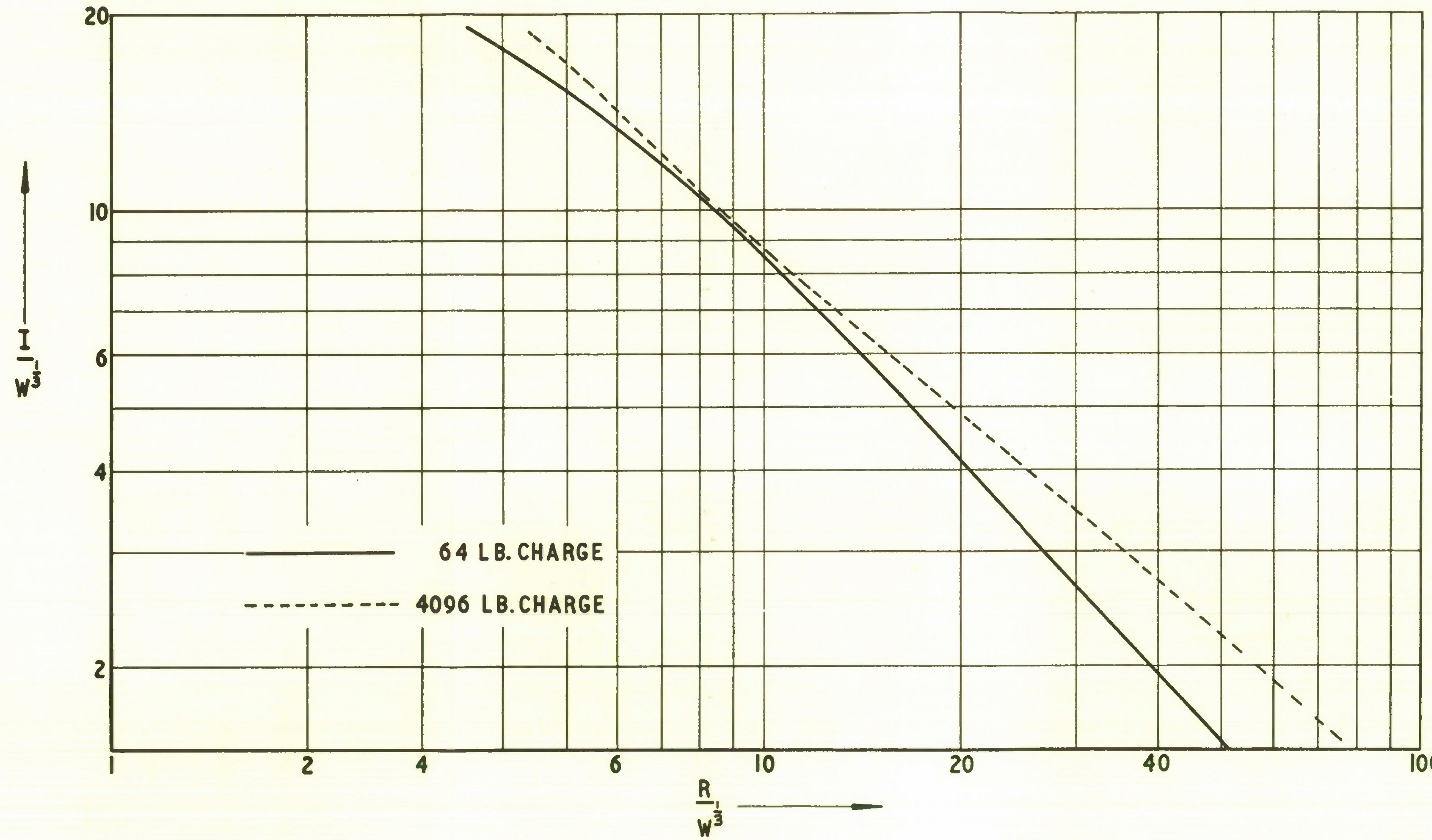

FIG. 17 SCALED IMPULSE - DISTANCE CURVES FOR 64 AND 4096 LB. CHARGES

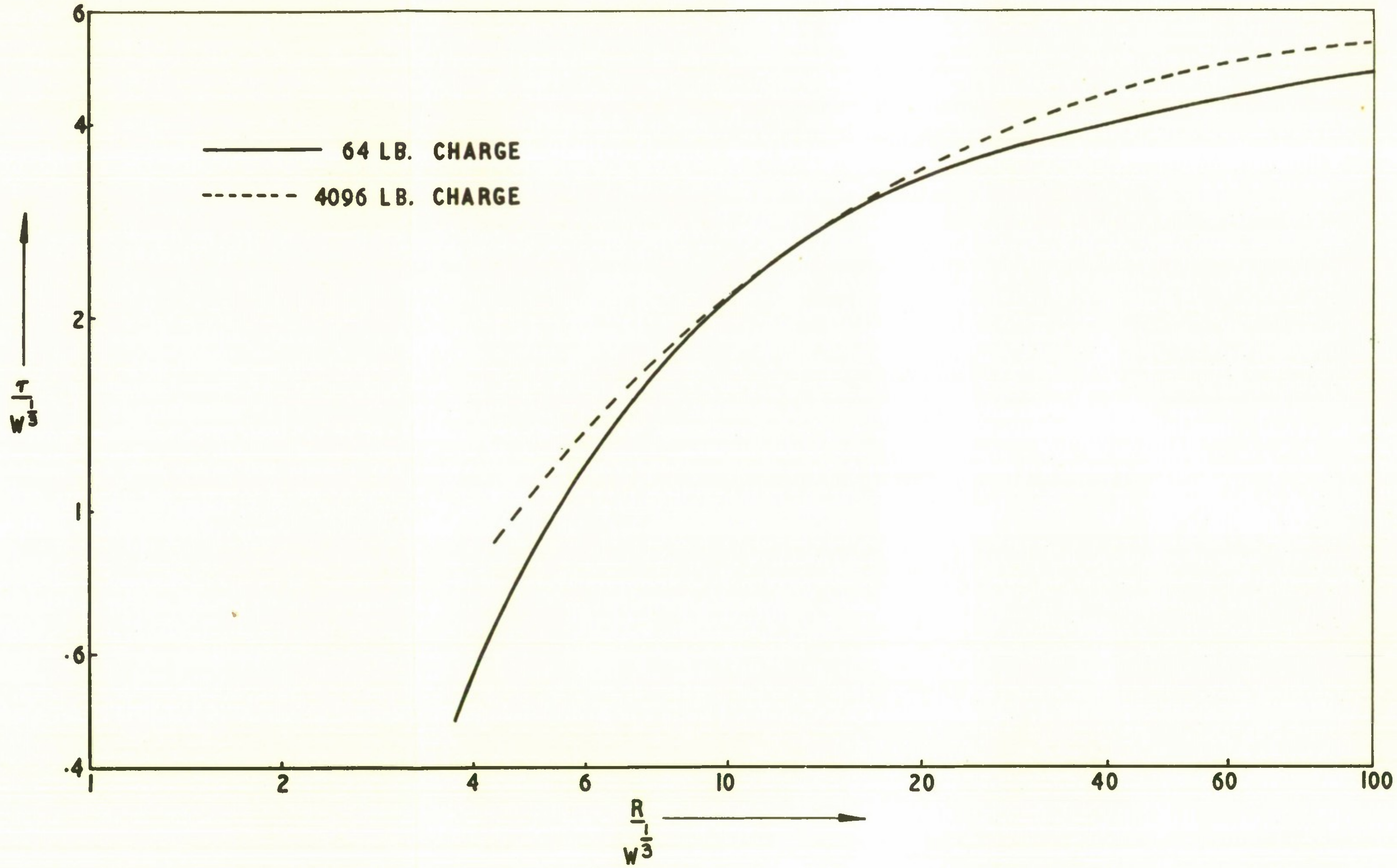

FIG. 18 SCALED DURATION-DISTANCE CURVES FOR 64 AND 4096 LB. CHARGES

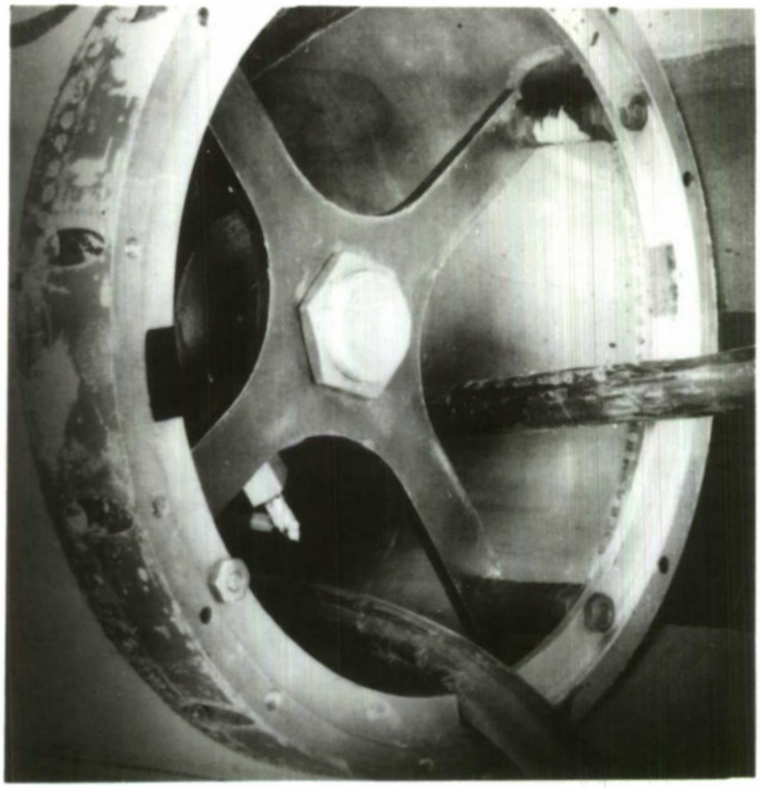

FIG. 19 MODIFIED RESILIENT MOUNTING FOR BALLAST WEIGHTS
1/4 SCALE MISSILE

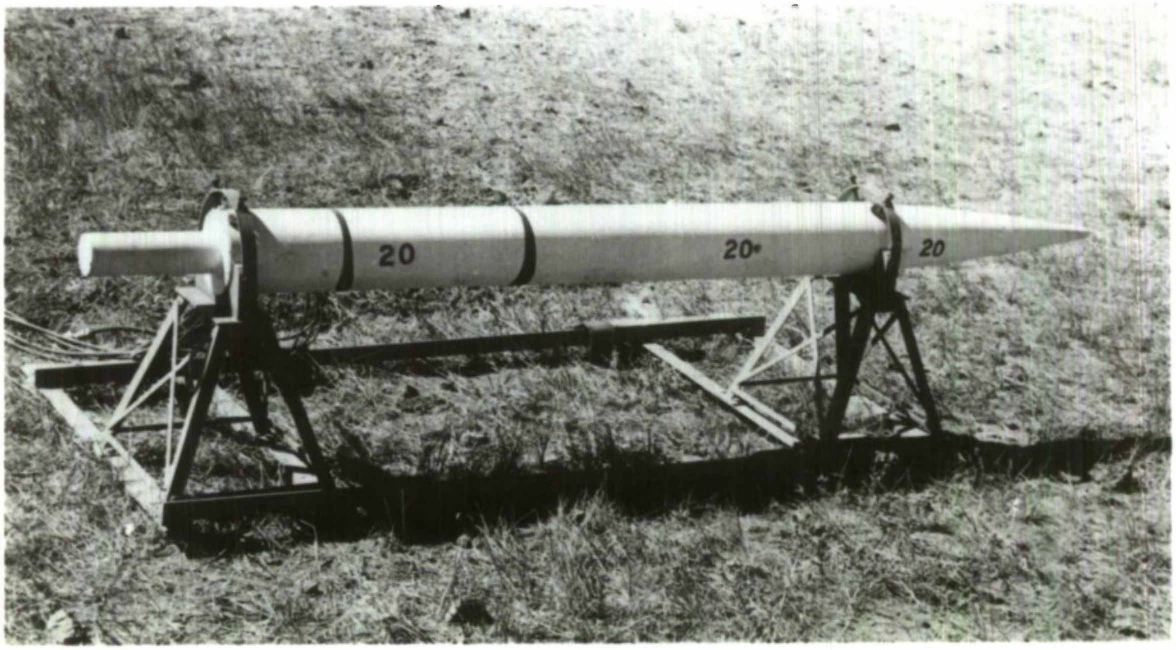

FIG. 20 1/4 SCALE MISSILE ON MODIFIED CRADLE MOUNTING

CONFIDENTIAL

Royal Armament Research and Development Establishment 534.222.2:
R.A.R.D.E. Memorandum 33/64 623.562.5:
623.451-519 Blue Water:
623.565.33.

Blast damage - The use of scaled models in the experimental study of the effects of air blast on missile structures.
F. King, D. C. Clenshaw, R. F. Lankshear July, 1964.

The use of scaled models and conventional H.E. charges in the study of the effect of blast from nuclear explosions is discussed.

Experimental work using full scale and one-quarter scale models of a representative missile and conventional explosive charges of 64 lbs. and 4096 lbs. is described.

13 pp. 20 figs. 7 tabs. 6 refs.

CONFIDENTIAL

CONFIDENTIAL

Royal Armament Research and Development Establishment 534.222.2:
R.A.R.D.E. Memorandum 33/64 623.562.5:
623.451-519 Blue Water:
623.565.33.

Blast damage - The use of scaled models in the experimental study of the effects of air blast on missile structures.
F. King, D.C. Clenshaw, R. F. Lankshear July, 1964.

The use of scaled models and conventional H.E. charges in the study of the effect of blast from nuclear explosions is discussed.

Experimental work using full scale and one-quarter scale models of a representative missile and conventional explosive charges of 64 lbs. and 4096 lbs. is described.

13 pp. 20 figs. 7 tabs. 6 refs.

CONFIDENTIAL

CONFIDENTIAL

Royal Armament Research and Development Establishment 534.222.2:
R.A.R.D.E. Memorandum 33/64 623.562.5:
623.451-519 Blue Water:
623.565.33.

Blast damage - The use of scaled models in the experimental study of the effects of air blast on missile structures.
F. King, D. C. Clenshaw, R. F. Lankshear July, 1964.

The use of scaled models and conventional H.E. charges in the study of the effect of blast from nuclear explosions is discussed.

Experimental work using full scale and one-quarter scale models of a representative missile and conventional explosive charges of 64 lbs. and 4096 lbs. is described.

13 pp. 20 figs. 7 tabs. 6 refs.

CONFIDENTIAL

CONFIDENTIAL

Royal Armament Research and Development Establishment 534.222.2:
R.A.R.D.E. Memorandum 33/64 623.562.5:
623.451-519 Blue Water:
623.565.33.

Blast damage - The use of scaled models in the experimental study of the effects of air blast on missile structures.
F. King, D. C. Clenshaw, R. F. Lankshear July, 1964.

The use of scaled models and conventional H.E. charges in the study of the effect of blast from nuclear explosions is discussed.

Experimental work using full scale and one-quarter scale models of a representative missile and conventional explosive charges of 64 lbs. and 4096 lbs. is described.

13 pp. 20 figs. 7 tabs. 6 refs.

CONFIDENTIAL

[redacted]

~~CONFIDENTIAL~~

U. K. Restricted

THIS DOCUMENT IS THE PROPERTY OF H.B.M. GOVERNMENT AND ATTENTION IS CALLED TO THE PENALTIES ATTACHING TO ANY INFRINGEMENT OF THE OFFICIAL SECRETS ACTS

It is intended for the use of the recipient only, and for communication to such officers under him as may require to be acquainted with its contents in the course of their duties. The officers exercising this power of communication are responsible that such information is imparted with due caution and reserve. Any person other than the authorised holder, upon obtaining possession of this document, by finding or otherwise, should forward it together with his name and address in a closed envelope to:—

PERMANENT UNDER-SECRETARY, WAR OFFICE, WHITEHALL, LONDON, S.W.1.

Letter postage need not be prepaid, other postage will be refunded. All persons are hereby warned that the unauthorised retention or destruction of this document is an offence against the Official Secrets Acts.

~~CONFIDENTIAL~~

U. K. Restricted

Information Centre
Knowledge Services
[dstl] Porton Down
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD 352431

Date of Search: 10 December 2008

Record Summary: DEFE 15/1980

Title: Blast damage: use of scaled models in the experimental sudy of effects of air blast on missile structures
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) Memorandum 33/64
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as <u>UNLIMITED</u>.